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Investigating the Martian atmosphere using the ExoMars 2016 lander

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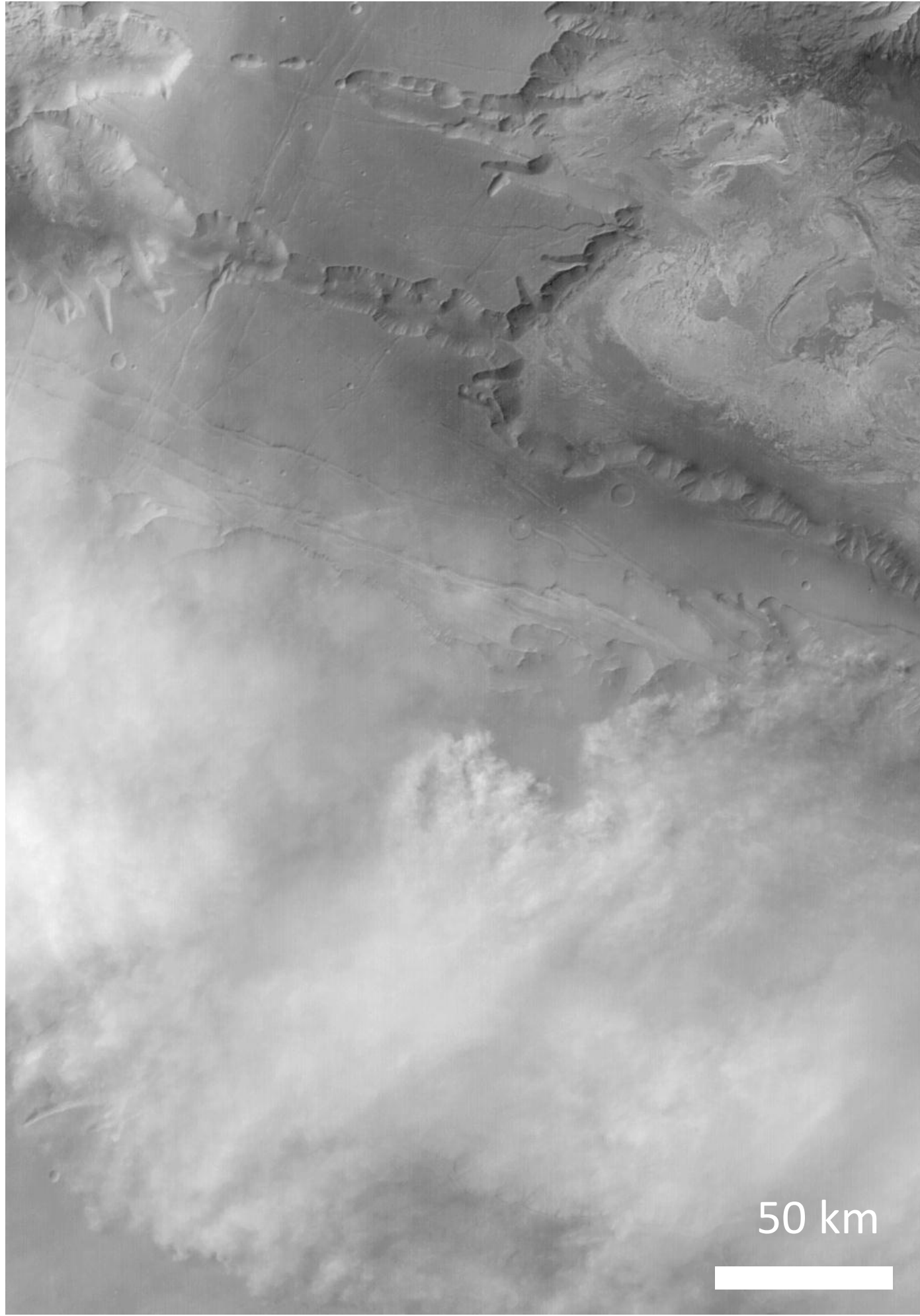


Figure 1

A local dust storm captured in an image from the Mars Orbiter Camera (MOC) aboard Mars Global Surveyor (MGS) (image centred on 8°S, 77°W). The storm is in Melas Chasma of Valles Marineris, its extent and edges clearly visible against the darker surface.

Image credit: NASA/JPL/Malin Space Science Systems

Martian Dust Storms

Dust within the Martian atmosphere is radiatively active: it absorbs solar radiation and re-radiates at infrared wavelengths, heating the surrounding atmosphere. This heating affects local winds, the lifting of dust from the surface, and the transport of dust throughout the atmosphere. The changes in wind patterns and dust distribution affect surface geological processes as well as modifying the planet's climate.

Large dust storms are a hazard for spacecraft landing on Mars, and the amount of dust present in the atmosphere may impact performance after reaching the surface. Regional or local storms may be more of a threat than global storms, due to the potential for wind shear and density gradients at storm edges, which could impact spacecraft landing profiles.

We are investigating the factors that affect the formation, growth and variability of regional storms, and studying the impact on the Martian climate of the variability of surface and atmospheric dust. A greater understanding of the current Martian climate will enable more confident calculations of past environments, and accurate predictions of atmospheric conditions, including dust storms, will inform future mission planning.

Atmospheric Modelling

Accurate modelling of the Martian atmosphere is essential for planning and completing future surface missions, and for appropriate analysis and interpretation of the returned data.

A Global Circulation Model (GCM) is a numerical model that simulates atmospheric circulation, and can model physical processes that range in scale from hundreds of kilometres to global scales. These models are used for conducting experiments that test climate and environmental hypotheses, and for predicting future climate patterns and events. The Mars GCM (MGCM) in operation at The Open University is a global, multi-level spectral model of the lower and middle portions of the Martian atmosphere. Physical processes that are too small to be modelled explicitly within the global scale model are parameterised in sub-models.

A mesoscale model is able to simulate atmospheric processes on scales down to a few kilometres. The Open University's mesoscale model allows studies of topographically-forced atmospheric elements, including large-eddy simulations.^[1]

Surface dust lifting, transportation and sedimentation are simulated in both the global and mesoscale models, allowing investigations into the growth, behaviour and decay of dust storms.

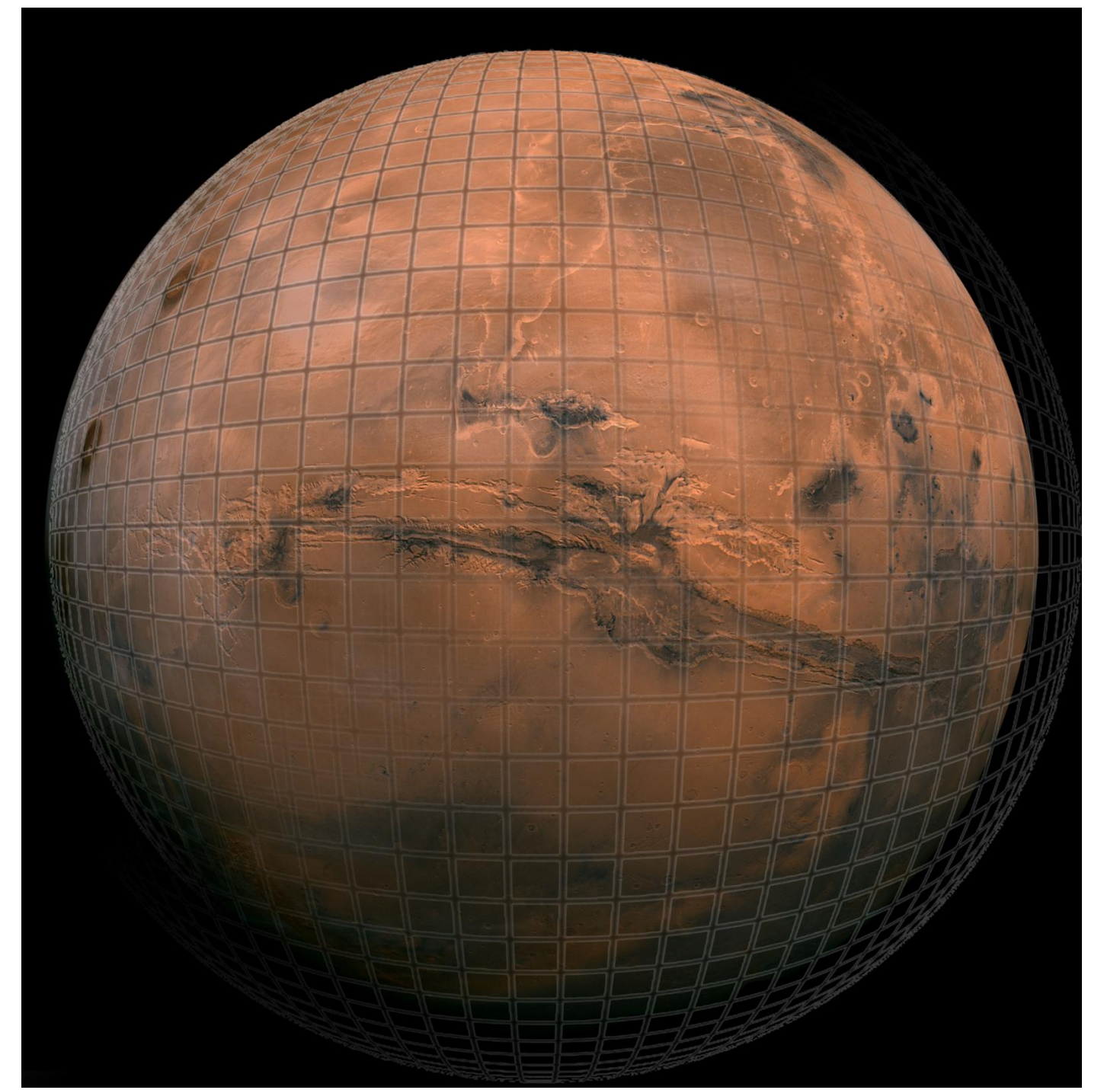


Figure 2

MGCMs divide the atmosphere into a grid of latitude by longitude by height. Sub-models operate within this grid to implement parameterisations of physical processes. Base image: NASA/JPL-Caltech Viking mosaic

ExoMars Entry, Descent and Landing Demonstrator Module

The ExoMars 2016 mission will carry an Entry, Descent and Landing Demonstrator Module (EDM), also known as Schiaparelli. This module is primarily designed to prove the ability of ESA's lander technology to safely carry an operational science package to the surface of the planet.^[2] EDM will land on Mars as the planet approaches perihelion and enters the dust storm season, offering the potential for an unprecedented insight into the Martian atmosphere at this time of year.

The EDM AMELIA (Atmospheric Mars Entry and Landing Investigations and Analysis) team will study data captured during the module's descent with the goal of characterising the structure of the Martian atmosphere along the travelled landing profile.^[3]

Primarily exploiting the EDM's reporting of engineering data, the team aim to combine data from multiple sensors and sources in order to reconstruct the module's trajectory from high altitude to the planet's surface. The aim is to derive atmospheric vertical profiles of density, pressure, temperature, and wind speed. Attempts will also be made during the descent to obtain the atmospheric dust opacity as a function of altitude.

The vertical profiles obtained during the EDM's descent will be incorporated into both the MGCM and mesoscale model. These combined datasets will improve the accuracy of The Open University's atmospheric modelling capability and enable more confident predictions of the environment that future Mars landers will encounter.

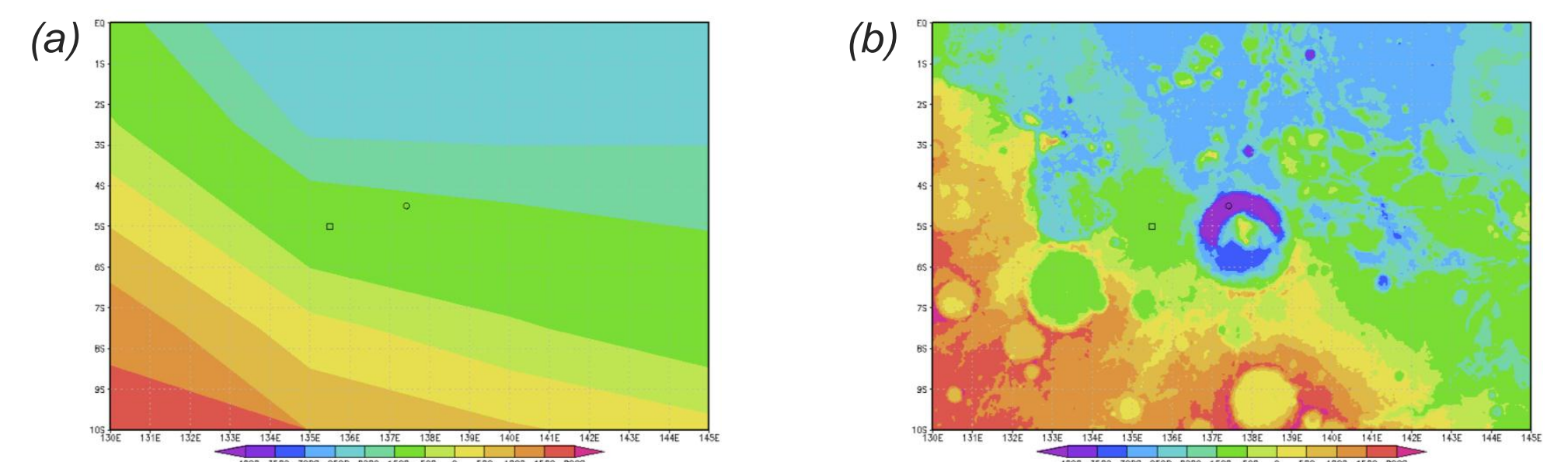


Figure 3

Accuracy at local scales depends on simulating small-scale processes within a global context. Data assimilation can be used to improve the prediction of model atmospheric fields, such as temperature and surface pressure. (a) Typical global model field (in this case, around the NASA Curiosity landing site). Smaller scale features can modify these fields considerably and are very important for localised predictions. In order to obtain detailed predictions it is necessary to either embed a mesoscale model in a global model or interpolate other atmospheric fields, such as temperature or (b) very high resolution topography.^[4]



Figure 4

A structural model of the ExoMars Entry, Descent and Landing Demonstrator Module during preparations for vibration testing.

Image credit: ESA, Anneke Le Floch'h

Modelling Surface Dust Lifting

Using the MGCM we are investigating the two mechanisms that lift dust from the surface of the planet: lifting by near surface wind stress and lifting by dust devils.

Dust devils, atmospheric vortices with low central pressures and high tangential and vertical winds, are generally considered to give rise to the background haze of dust in the Martian atmosphere. Dust devils are small in scale and are parameterised within the model.

Near surface winds are proposed as the driving force behind the formation and growth of dust storms. Dust lifting by near surface wind stress is simulated using the strength of the wind at the planet's surface, as calculated from large scale winds.

Current studies include the dependence of dust lifting on near surface winds associated with small-scale features. These features are not well-represented at low resolution; their impact on local and regional dust storms is unclear. As this scale of storm may be hazardous to landing spacecraft, understanding these storms and the related variability in atmospheric temperature, density and wind speeds, is crucial for future mission planning.

Simulations are being completed across increasing model resolutions in order to investigate this dependence relationship, aiming to improve the accuracy of dust lifting within the MGCM, and hence improve the analysis and prediction of dust storms.

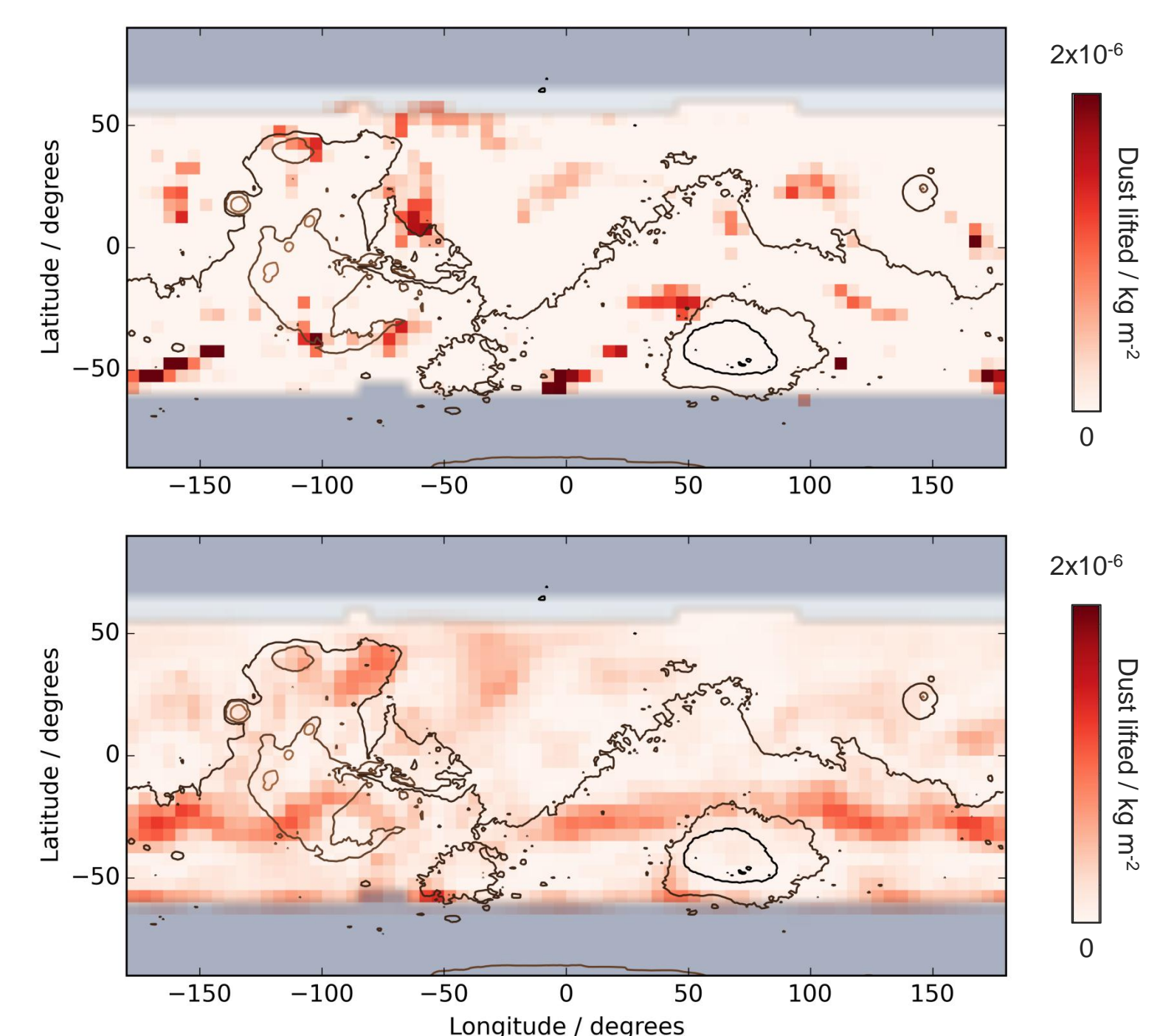


Figure 5

Total dust mass lifted (kg m^{-2}) by near surface wind stress (top) and dust devils (bottom) within one Martian month during the planet's Northern Hemisphere winter. Darker red indicates a higher level of dust lifting at that grid-point. Grey regions identify extent of seasonal polar ice caps.

References

- [1] Spiga and Lewis (2010). Mars 5, 146-158; doi:10.1555/mars.2010.0006.
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- [4] Lewis et al. (2007). Icarus, 192(2), pp. 327-347.